THE FUTURE OF SPACE ENVIRONMENT MONITORING IN LOW EARTH ORBIT (IN31A-1271)

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During the next decade there will be significant changes in the availability and mission effectiveness of space environmental data provided by U.S. operational environmental satellites in low-earth orbit (LEO). On the one hand, the cancelation of the National Polar-orbiting Operational Environmental Satellite System (NPOESS) and the programmatic changes that had preceded this cancelation have had a deleterious impact on planned National space environmental monitoring capabilities across a broad spectrum of environmental parameters. However, space environmental records available from remaining and planned operational satellite systems offer some improved capabilities and reduced latencies to better serve National space weather needs. Full utilization of the capabilities offered by these system upgrades within operation centers will require careful planning investments for which the Office of Federal Coordinator for Meteorology (OFCM) can provide guidance through the Committee for Space Weather (CSW). This talk will provide an overview of current sources of space environmental data from LEO satellites in polar orbit and planned capabilities using data from satellites in both polar and lower inclination orbits.

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BACKGROUND

In February 2010 the President formally canceled the National Polar-orbiting Operational Environmental Satellite System (NPOESS). Rather than a single tri-agency program providing operational environmental data in three distinct orbits as was originally envisioned, the NPOESS program was split into two segments consisting of civilian and military components. The DoD/United Stated Air Force (USAF) is responsible for providing environmental monitoring in the terminator orbit (0530 Local Time [LT]) whereas the DOC/National Oceanic and Atmospheric Administration (NOAA) is responsible for the early afternoon orbit (1330 LT). The NOAA element consists of a teaming arrangement with the National Aeronautics and Space Administration (NASA) for developing the Joint Polar Satellite System (JPSS). The overall JPSS architecture includes the European MetOp program consisting of a weather monitoring satellite in the mid morning orbit (0930 LT). The first JPSS satellite has a planned launch date in 2015 whereas the DWSS is scheduled for a 2018 launch. MetOp=A was launched in 2006.

In the original set of program requirements (circa 1996) it was planned that NPOESS would include a full complement of space environmental sensors in all three orbits; i.e those now covered by the JPSS, the DWSS and MetOp. Over time the set of sensors and sampling orbits were reduced due to sequential reprogramming efforts such that just prior to the NPOESS cancelation the remaining remnants of the full NPOESS Space Environment Sensor Suite were a set of energetic charged particle detectors referred to the Space Environment Monitor - NPOESS (SEM-N) manifested for the 1330 LT orbit plus the SEM-2 package on the MetOp at 0930 LT. In the aftermath of the NPOESS cancellation SEM-N (now referred to as SEM-Next) was removed from consideration for first JPSS but remains as an objective for JPSS-2. On the USAF side, the SEM-N is currently manifested on DWSS.

CURRENT OPERATIONAL LEO SATELLIITES

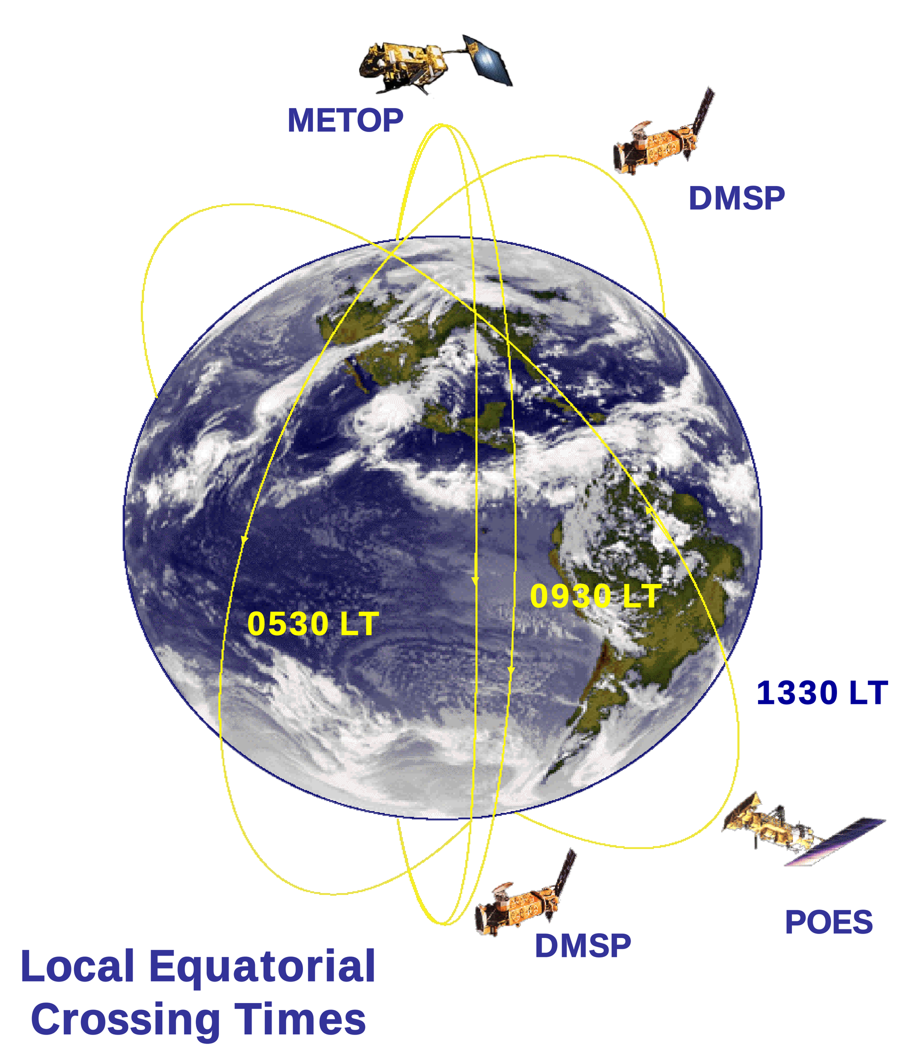

Figure 1. Current LEO satellites.

The current operational architecture for acquiring space environmental data in LEO consists of sensors on the Defense Meteorological Satellite Program (DMSP) and Polar Operational Environmental Satellite (POES) plus the current MetOp satellite, as depicted in Figure 1. Instrumentation on the POES and MetOp satellites includes the Space Environment Monitor (SEM-2) suite comprised of a Total Energy Detector (TED) for measuring electrons and protons in the energy range from 50 eV to 20 keV and a Medium Energy Proton and Electron Detector (MEPED) for measuring medium-energy electrons (protons) from 30 keV to 1 MeV (>6.9 MeV) and solar protons from 16 MeV to 250 MeV. The SEM-2 sensors are pictured in Figure 2.

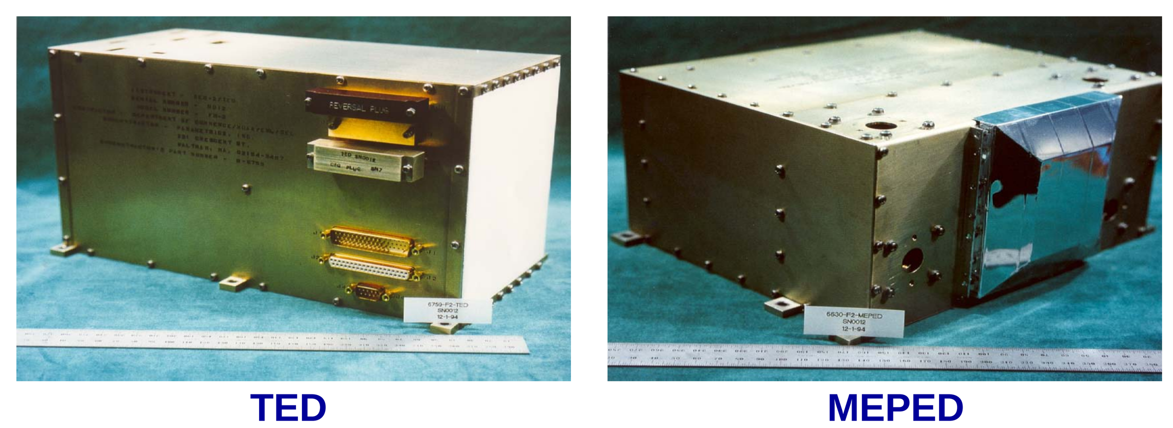

Figure 2. Photographs of the POES and MetOP SEM-2 sensors.

The current DMSP space weather sensors consist of an Auroral Particle Detector (SSJ5), a Thermal Plasma Sensor (SSIES), a vector Magnetometer, and a pair of ultraviolet limb (SSULI) and disk (SSUSI) spectrometers. Photographs for the DMSP space weather sensors are depicted in Figure 3.

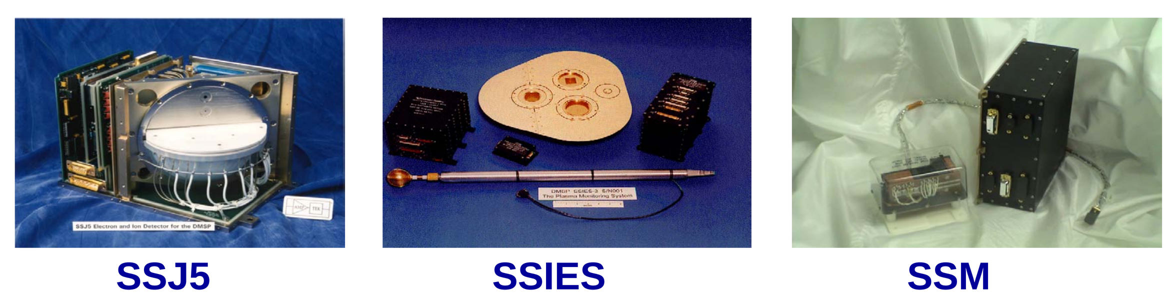

Figure 3. DMSP space sensors (SSUSI / SSULI not shown).

Space environmental data from DMSP and POES/MetOp are used to produce a number of operational products for the USAF and NOAA, respectively. Figure 4 depicts several derived products from the POES/MetOp whereas Figure 5 illustrates an advanced output from the USAF Global Assimilation of Ionospheric Measurements (GAIM) model.

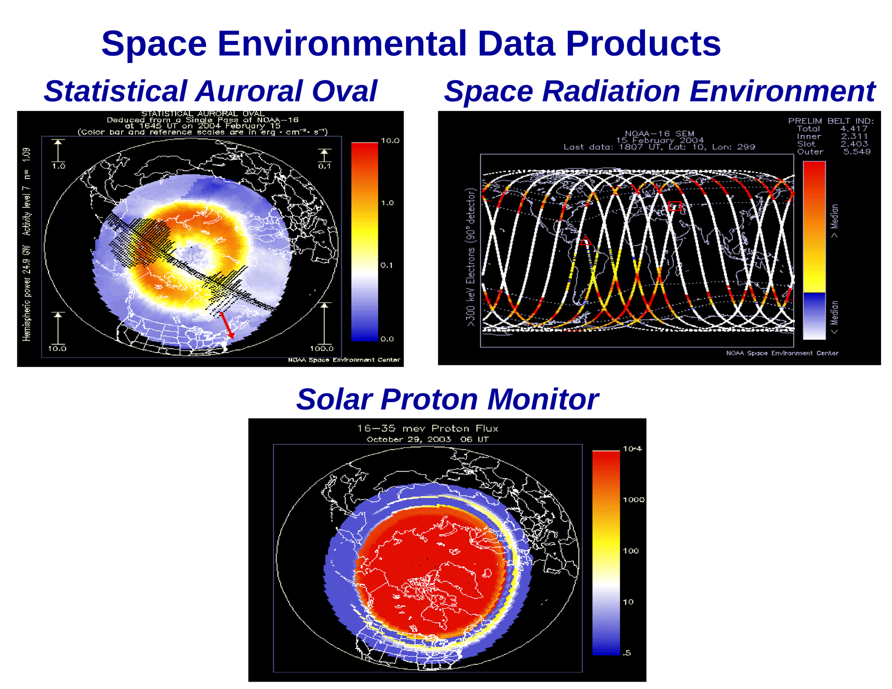

Figure 4. NOAA Space Weather Prediction Center products.

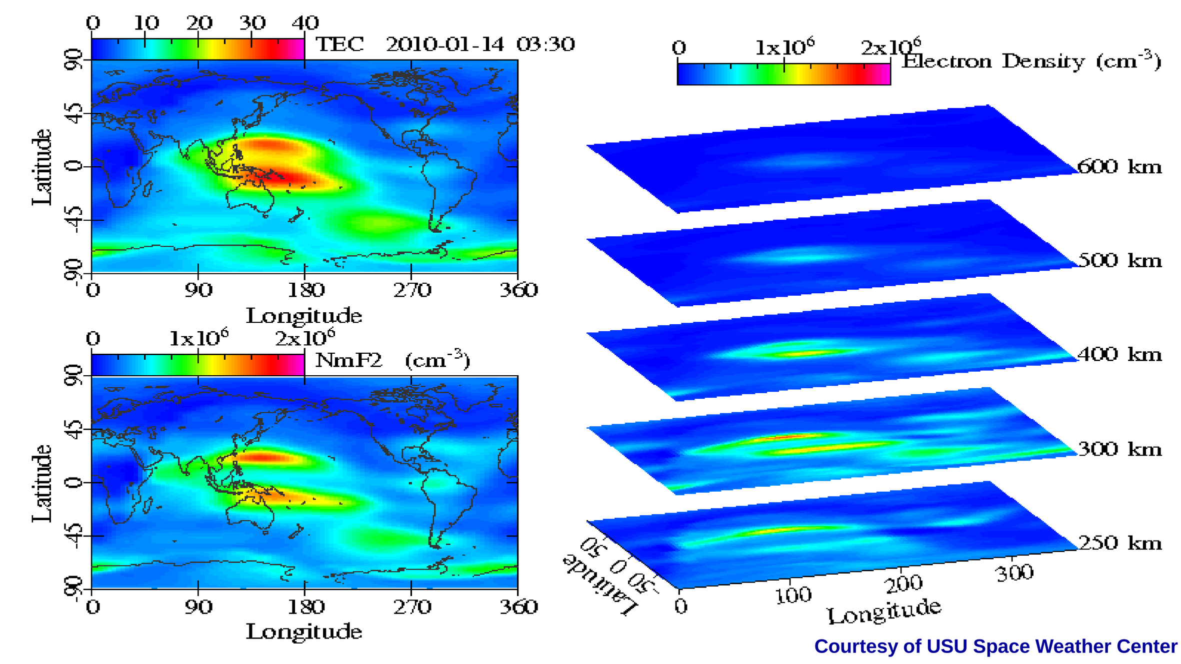

Figure 5. GAIM ionospheric total electron content (TEC).

FUTURE CAPABILITIES

After the end of life for the DMSP and POES, the availability of polar LEO data may be limited to that available from the MetOp SEM-2 and the SEM-N on DWSS and possibly JPSS-2 (see Figure 6). Overall, this future architecture represents a significant degradation compared to current capabilities. However, there are several potential mitigation strategies planned or under consideration that may better serve space weather operations.

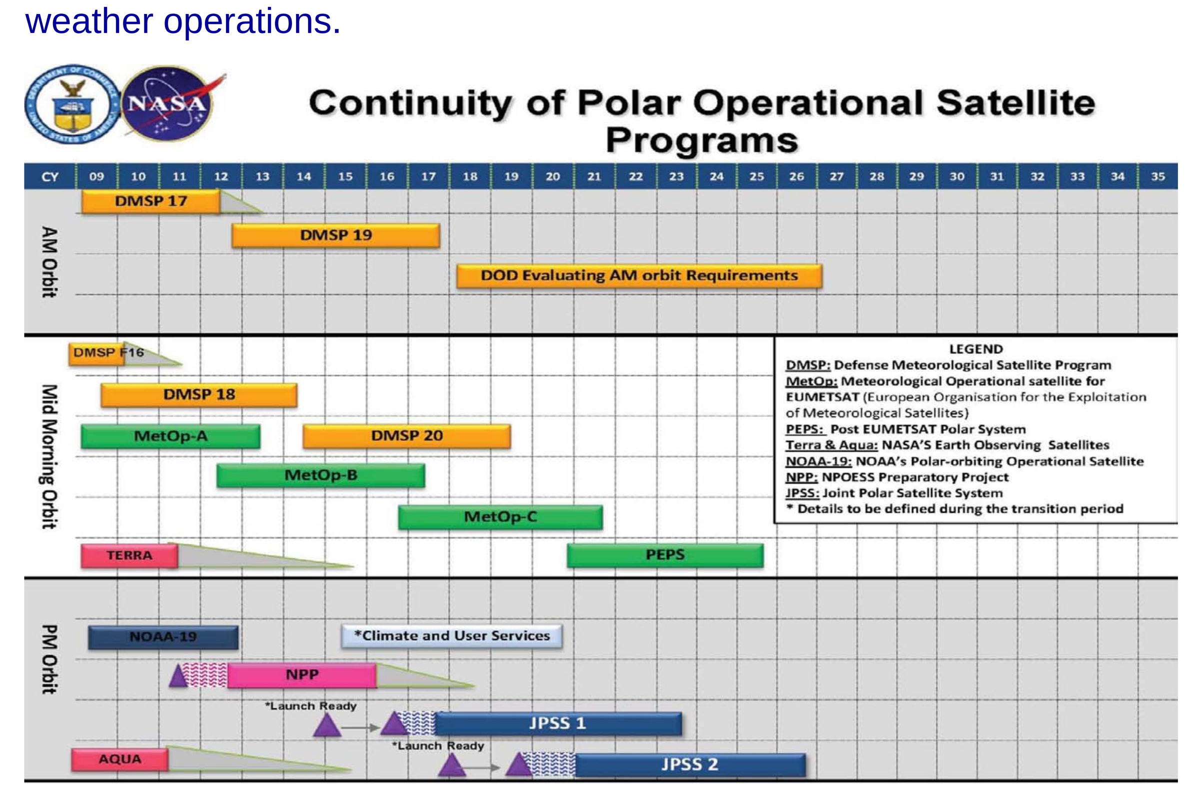

Figure 6. Polar operational satellite programs (2009 – 2026).

First, the SEM-N suite represents an improvement in capability from the heritage POES/MetOp SEM-2 suite. The SEM-N consists of three separate sensors; an SSJ5, an Energetic Particle Monitor (EPM) and a High Energy Sensor (HES) as depicted in Figure 7. The combination of these sensors in the SEM-N provides a contiguous energy range for protons (electrons) from 30 eV to 250 MeV (4 MeV) with improved spectral resolution and contamination rejection (Figure 8). In addition,

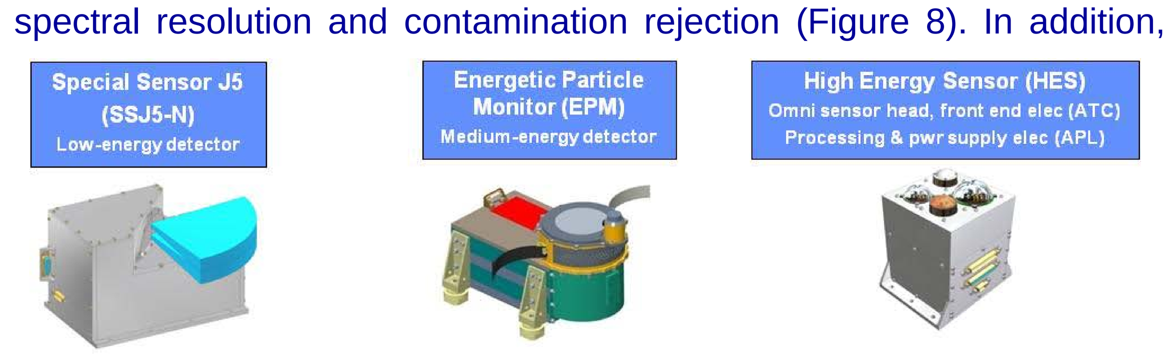

Figure 7. Sensor components for the SEM-N suite.

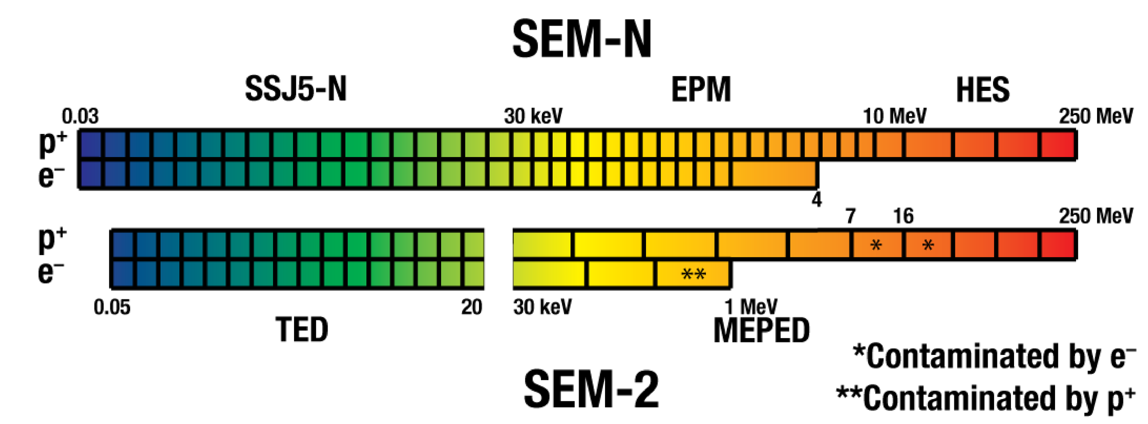

Figure 8. Energy range & resolution for the SEM-N and SEM-2 suites.

the DWSS/JPSS-2 will likely support a 15-minute latency (77% of data) which will greatly enhance the operational utility of the SEM-N data.

Second, the USAF is actively looking at options to recoup some of the anticipated loss of capability due to past restructuring of the NPOESS program. In 2009, the Air Force issued a Request for Information (RFI) on cost-effective ways to fulfill its requirements for space weather observations and other space environmental data. According to the RFI, "The Air Force is evaluating all possible solutions sets, including the employment of commercial systems as a data provider with sensors already on-orbit or hosting sensors on future platforms." The results of this RFI are being used by the USAF to help formulate future strategies for DoD space environmental monitoring.

NOAA is pursuing plans to field an operational follow-on to the Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC). Referred to alternatively as COSMIC-II or the Global Navigation Satellite System – Radio Occultation (GNSS-RO), this system will provide a global specification of the ionosphere using a 12-satellite constellation capable of 8,000 daily soundings; i.e. occultations. Phase 1 launch of COSMIC-II is planned for 2014.

In related areas, NOAA and the USAF are expanding their overall space environmental monitoring capabilities beyond LEO. Improvements are currently in progress for the next generation NOAA Geostationary Operational Environmental Satellite (GOES) sensors and algorithms which will provide better space weather data for operations. NOAA is also planning to field an operational follow-on to the NASA Advanced Composition Explorer (ACE) satellite to provide space weather data at the sun-earth Lagrangian L1 point. While additional discussions for the future GOES and the ACE follow-on are beyond the scope of this presentation, the improvements offered by these assets should be considered in any assessment of overall space environment monitoring capabilities as performed by the CSW at the request of the OFCM.

SUMMARY

Substantial changes are envisioned for the future availability of operational space environmental data from LEO satellites. Past restructurings and the eventual cancellation of the NPOESS program will likely result in an overall degradation in space environmental monitoring capabilities at the end of the current DMSP and POES program unless mitigation strategies are effectively implemented. While the performance and timeliness of energetic charged particle data from the next generation SEM suite on the DWSS and possibly the JPSS-2 is certainly welcomed, the potential loss of other environmental data records currently provided by DMSP and previously planned for the NPOESS will be sorely missed. Both the USAF and NOAA are pursuing strategies to recoup some of this lost capability. On the other hand, the future of space environmental monitoring at GEO and, hopefully, L1 is somewhat brighter.